USING PRECAST REINFORCED-CONCRETE SETS IN THE PIONEER TUNNEL OF GREAT NORTHERN RAILWAY'S CASCADE TUNNEL, KING COUNTY, WASH.

By E. W. Parsons

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USING PRECAST REINFORCED-CONCRETE SETS IN THE PIONEER TUNNEL OF GREAT NORTHERN RAILWAY'S CASCADE TUNNEL, KING COUNTY, WASH.[1]

by

E. W. Parsons[2]

SUMMARY AND INTRODUCTION

Permanent support of the back is an important economic factor in maintaining a tunnel or other underground opening in condition to render the service for which it was driven. Timber has been most commonly used for support in tunneling and drifting because of its strength and ease of installation.

Even when treated for decay, however, timber is subject to deterioration and, over a long period of time, should not be considered a permanent support. Concrete support or lining is permanent and has been used in tunnels of every size for many years but has been almost exclusively cast in place, a difficult, costly process. This report deals with the design and installation of precast concrete supports to combine the best features of both methods.

The Great Northern Railway has a number of tunnels on the line crossing the Cascade Mountain Range in western Washington; the longest (7.79 miles, known as the Cascade tunnel) was completed in 1928. The parallel Pioneer tunnel, 66 feet to the south, was driven simultaneously to service the Cascade tunnel and is now used for drainage.

The Cascade tunnel was lined with concrete during construction; the Pioneer tunnel was supported with conventional timber, some of which has since been replaced 2 or 3 times. In 1939 timber in two sections of heavy ground near the portal was replaced by cast-in-place concrete. Because of the expense of this method, precast reinforced-concrete sets were developed in 1944, and 50 linear feet of sets, placed "skin-to-skin," were installed the first year. Since then precast-concrete installations have been made in 1947, 1948, 1949, 1950, 1954, 1956, and 1957, averaging about 225 linear feet each year. By the end of 1957 the total footage of sets placed was 1,580 feet or, roughly, 2,370 sets.

The cost of concrete sets will vary, depending upon local labor wages and the cost of materials, but, in general, it is somewhat higher than that for comparable wood sets. Standard sand and gravel was used with good results, although some form of lightweight aggregate might be investigated for lighter construction. In future application of precast-concrete sets, rock from a tunneling or mining operation might be crushed, sized, washed, and used as a substitute for sand and gravel.

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GENERAL INFORMATION[3]

The Great Northern Railway has the northernmost right-of-way of any transcontinental railroad in the United States. Crossing the Cascade Range proved to be one of its most complicated problems; in fact, it was one of the most difficult railroad crossings in the entire West, and it was not until 1893 that a crossing was completed at Stevens Pass. The first Cascade tunnel - 2.7 miles in length - was opened in 1900, and a switchback route with 4-percent grades over the open pass was eliminated. By 1925 the right-of-way between Merritt and Scenic, Wash., a distance of 24 miles, had 32,322 feet of snowsheds and 19,332 feet of tunnel or, roughly, two-fifths of the distance. Some of these snowsheds had cost $175 per linear foot when built and by 1925 could not be replaced for $210 per foot. The ever-increasing cost of construction and maintenance provided the incentive for locating a route that would eliminate the principal snow-slide areas. After considerable study a route was chosen whereby a tunnel approximately 8 miles long could lower the summit-crossing elevation 501 feet and shorten the track length 7.68 miles, including 6.04 miles covered by snowsheds. Work on the tunnel was begun in December 1925 and completed in January 1929. The east portal is in Chelan County and the west portal in King County. The tunnel was completed by driving from both ends, sinking a 622-foot shaft to tunnel grade, and driving both ways from the shaft bottom. A parallel tunnel, the Pioneer, was driven 9 feet wide by 8 feet high, 66 feet off center from the Cascade tunnel, and was connected to it by crosscuts spaced 1,000 to 2,400 feet apart. The total length of the Cascade tunnel is 7.79 miles and of the Pioneer tunnel 5.3 miles. The Pioneer tunnel extends from its portal to the shaft, so it may be considered an adit. Work westward from the shaft bottom included driving the Pioneer face, as well as the Cascade-tunnel face. The west portal of the Cascade tunnel had an elevation of 2,247 feet and the east portal an elevation of 2,881 feet. The tunnel grade is 1.565 percent. The Pioneer-tunnel portal elevation is 2,256 feet.

The water from the Pioneer tunnel in places flows 2 or 3 inches above the top of the rails. Although there has been some deterioration due to oxidation, the track, laid when the tunnel was driven, will be serviceable to permit repair and inspection of the two tunnels for many years.

Use of electric locomotives in the Cascade tunnel has recently been discontinued and diesel locomotives are now used exclusively. Large fans have been installed at the east portal to clear diesel exhaust fumes and are operated whenever a train is in the tunnel and until contaminated air has been replaced. There are 28 scheduled

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[3] The following publications were used as references in preparing this paper:
Skerrett, Robert G., Great Northern Railway Driving Long Tunnel Through Cascade Range: Repr. from Compressed Air Magazine, March, April, and May, 1927.
Kerr, D. J., Mears, Frederick, and Baxter, J. C., The Eight-Mile Cascade Tunnel, Great Northern Railway, a Symposium: Repr. from Proc. ASCE, February 1931, pp. 183-268.

Original from THE OHIO STATE UNIVERSITY

trains through the tunnel daily, mostly freights, though traffic varies with the seasons and with economic conditions.

DESIGN OF CONCRETE SETS

Precast reinforced-concrete sets can readily be designed to withstand great stresses. The sets for the Pioneer tunnel were designed for a superimposed load of 3,000 pounds per square foot on roof slab and 1,500 pounds per square foot on sidewalls to replace 12- by 12-inch timber sets random-spaced from 3 to 8 feet. The concrete was specified to meet Great Northern specification "A-1" ($f_s = 18{,}000$ pounds, $f_c = 1{,}000$ pounds). The sets are made in Everett, Wash., of transit-mix concrete and new billet deformed, intermediate-grade, reinforcing steel. Sets are placed "skin-to-skin" and thus form a continuous lining. A continuous reinforced-concrete footing supports the sets. The weight of individual members was not a critical factor, so no consideration was given to the use of lightweight aggregate (fig. 1).

Size and Weight

A set as placed is comprised of three precast members and is placed on a continuous concrete footing. The footing is cast one side at a time in units of 12 feet for whatever distance old posts or other obstacles can be conveniently cleared. Details of the concrete members follow:

TABLE 1. - Dimensions of set

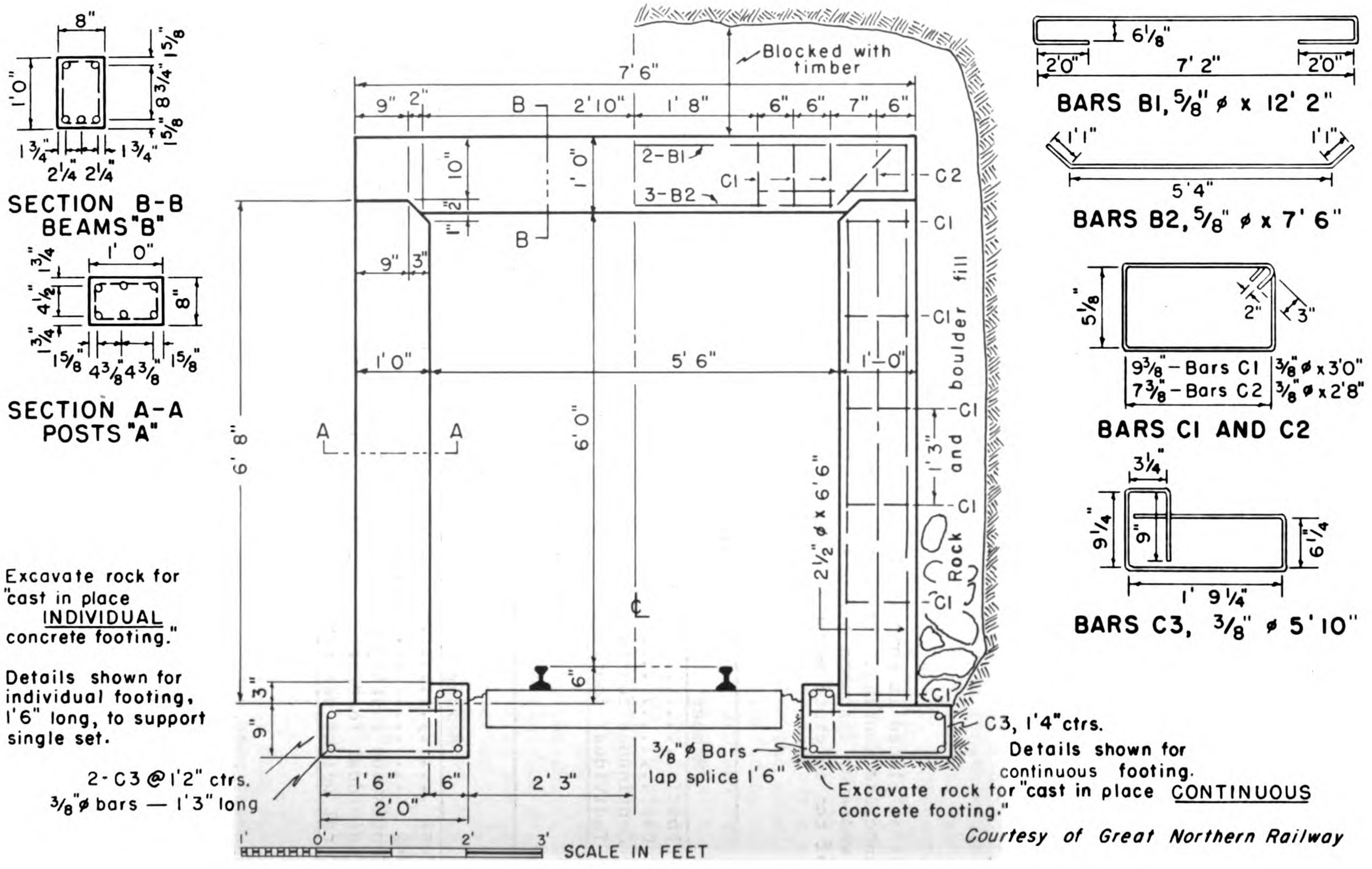
Member	Number required	Size
Post	2	8 x 12 in. x 6 ft. 8 in,
Cap	1	8 x 12 in. x 7 ft. 6 in.
Continuous footing.	2	9 x 24 in. with 3 x 6 in. curb
Individual footing.	2	9 x 18 x 24 in.

TABLE 2. - Material per member

Member	Number required	Concrete, cu. ft.	Reinforcing steel, lb.	Weight each, lb.
Post	2	4.42	32.82	663
Cap	1	4.81	57.72	720
Continuous footing per ft.	(1 side)	1.13	3.5	
Individual footing	(1 side)	2.44	6.5	
Total weight per set				2,046

Casting

Twenty-eight sets are cast at a time at the Delta yard of the Great Northern Railway in Everett, Wash. A level platform roughly 10 feet wide by 75 feet long, is first constructed of 4-inch timber and covered with 22-gage galvanized sheet iron. The forms are erected on this platform. A rim of 4- by 12-inch timber is fastened to the top of the platform, and 8- by 12-inch spacers are set in place to divide the entire form into 6 sections containing 14 units. Dividers of 2- by 12-inch plank to separate individual members are placed in the sections and spaced at the ends with 2- by 8-inch blocks. A triangular piece fastened on the spacer block in one end of the post form gives the bevel at the top of the post; a beveled block



Excavate rock for "cast in place INDIVIDUAL concrete footing."

Details shown for individual footing, 1'6" long, to support single set.

2-C3 @ 1'2" ctrs.
3/8" ø bars — 1'3" long

Details shown for continuous footing.

Excavate rock for "cast in place CONTINUOUS concrete footing."

Courtesy of Great Northern Railway

FIGURE 1. - Concrete Lining for Great Northern Pioneer Tunnel No. 15, Scenic, Wash.

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on each spacer in the cap form produces the framing on the cap. Before the concrete is poured the forms are coated with a special oil to prevent the concrete from adhering to them. Only the triangular block in the post form and the bevel blocks in the cap form are damaged by removing the cast member and need to be replaced after each casting cycle. All timber is clear, dried, and dressed and is reused until the surfaces become worn or damaged (fig. 2).

Reinforcing steel delivered to the railroad yard, bent to specification, is assembled and placed in the forms. One man can assemble the steel for 1 cap in 25 minutes and for 1 post in 20 minutes (fig. 3). Concrete is ordered to specification and delivered by transit-mix trucks. An internal vibrator is used to settle concrete in the forms to prevent formation of submerged air pockets. In dry weather the cast members are sprinkled daily until the forms are removed. The forms are removed in 5 to 7 days and after cleaning are set up for another pour (fig. 4). A 28-day compression test shows the concrete to average about 4,000 p. s. i.

Twenty-eight sets constitute one railroad flatcar load, the usual shipment from Everett to the tunnel portal. The sets are loaded, six or more members at a time, by a crane and wire sling. Minor chipping of some of the sharp edges of the sets has no effect on their strength.

INSTALLATION

The company plans to install concrete sets over a total distance of 250 feet each installation. The maintenance foreman selects sections where the old timber is in poor condition, sections that may range from possibly 20 feet upward to whatever length is required (fig. 5). The first steps are to clear the floor on one side of the tunnel of old posts and to clean the floor to solid rock, after which forms and reinforcing steel for a footing are installed (fig. 6). Old timber posts are replaced by a temporary center post or sprag to the sidewall; caps are temporarily supported by a timber jumbo, designed to handle concrete sets,while the posts are being replaced. The footing usually is installed in units of 12 feet; 1 to 4 units may be placed simultaneously, although in bad ground it may be impossible to clear even 12 feet. Water flowing in the tunnel is diverted to the opposite side when the forms are placed and while the concrete is being poured. Aggregate is brought in from the portal, and the concrete for footings is mixed by hand at the point used. As soon as the concrete is set, work on the opposite side of the tunnel is begun. Individual footings for isolated sets were included in the original design, but no separate sets have yet been used (fig. 7).

A small locomotive transports materials to the work site. A special flatcar is used to carry a complete set into the tunnel. The two posts lie on the car bed and support one end of the cap; the other end rests on a roller built into the car. A timber jumbo, designed by the maintenance crew and manufactured in the railroad shops in Everett, raises the cap into place and supports it until the posts are placed (figs. 8 and 9). The cap is rolled off the car onto a swivel support on the front of the jumbo and raised into place by a 5-ton hand-cranked hoist. Slight unevenness in the thickness of the sets occasionally makes it necessary to plumb them by means of wedges. As placing of the sets progresses, the space behind them is backfilled to whatever height the available rock will reach. The remaining space on the sides and over the top is packed solid with old timber (fig. 10). The first sets placed have been in service 9 years and give no indication of taking weight or of movement.

CONCLUSIONS

The precast-concrete sets installed in the Pioneer tunnel are a permanent support and will reduce maintenance to little more than an occasional inspection tour.

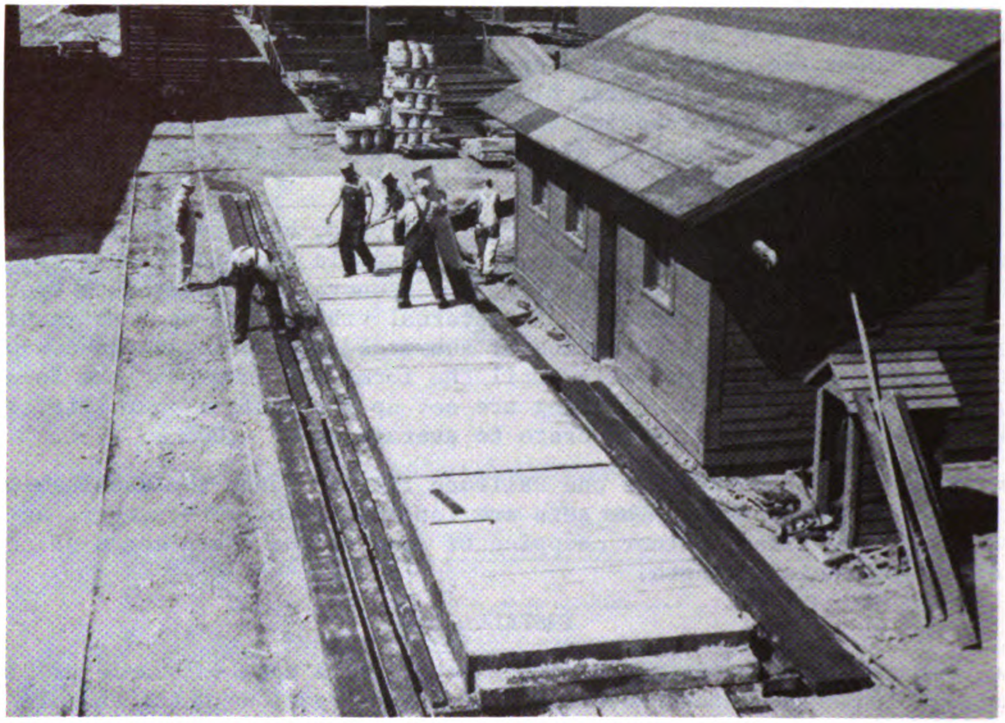

FIGURE 2. - Form for Casting 28 Sets.

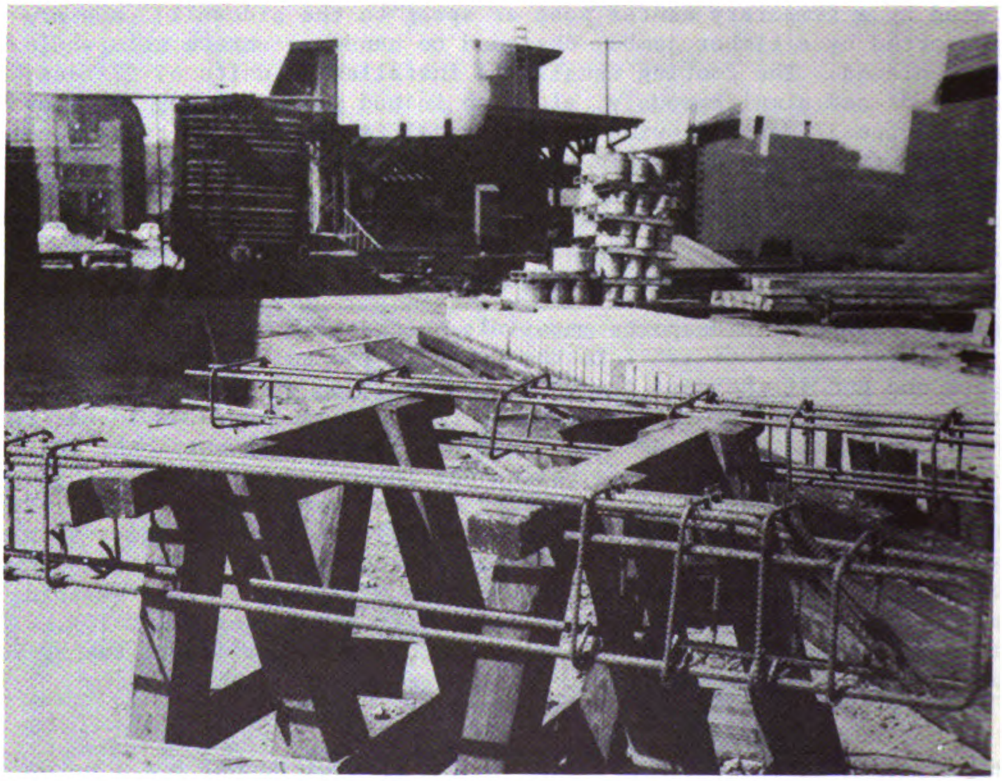

FIGURE 3. - Reinforcing Steel for Cap and Post.

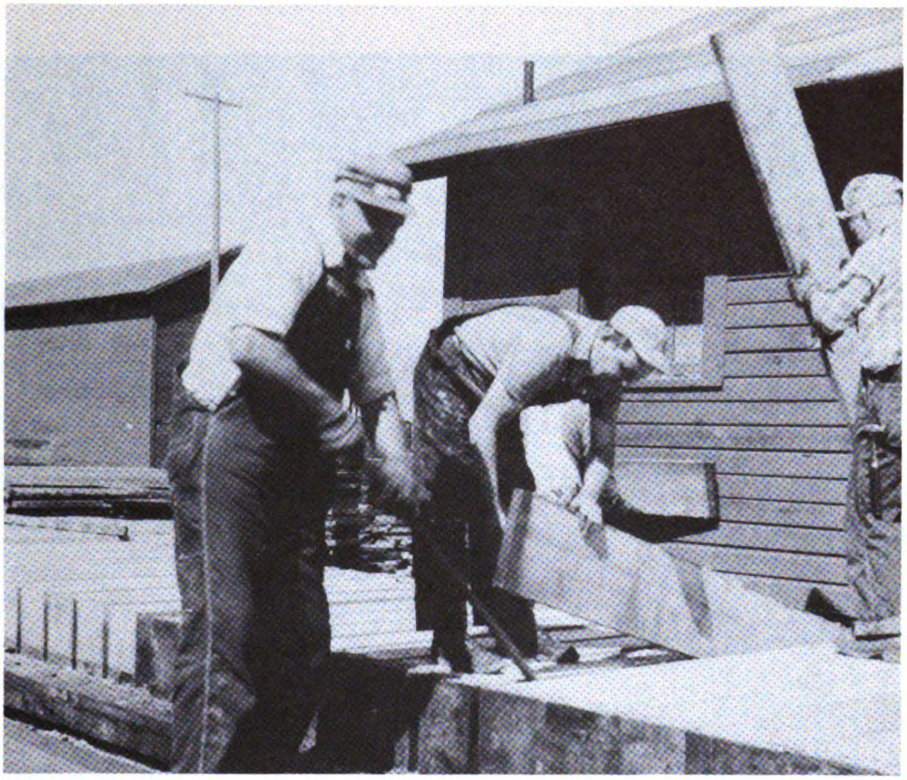

FIGURE 4. - Stripping Forms.

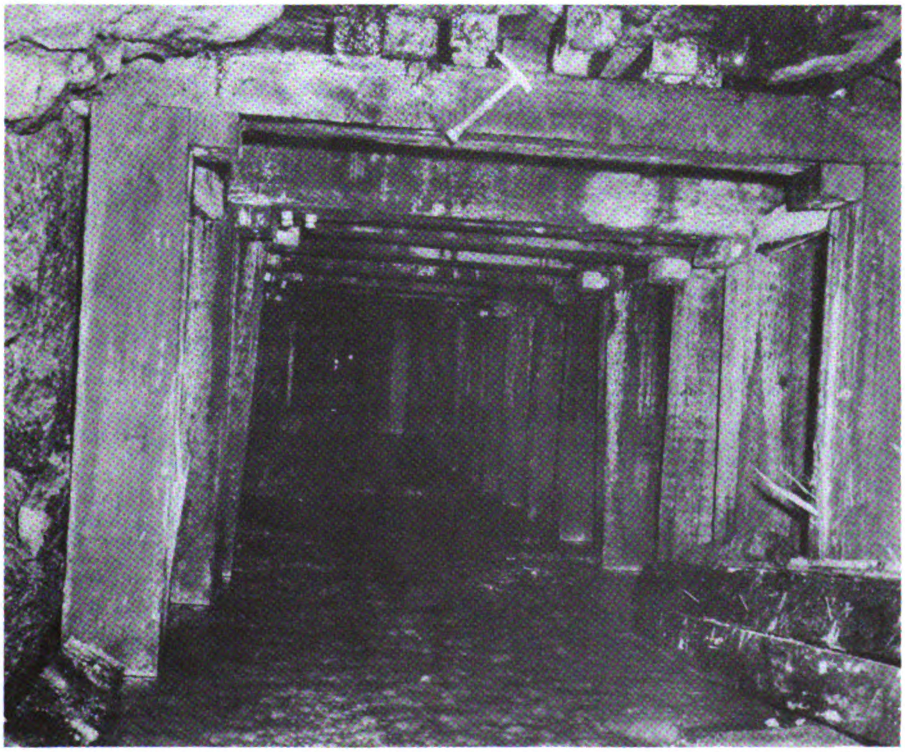

FIGURE 5. - Timber Sets to Be Replaced.

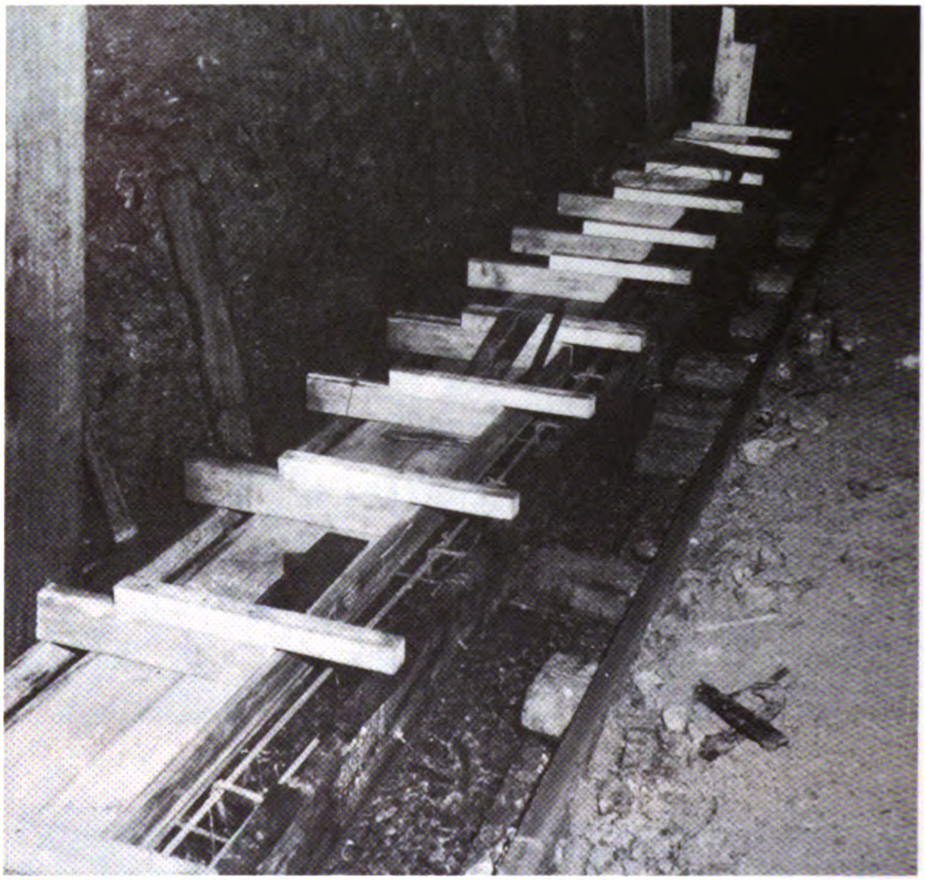

FIGURE 6. - Forms and Steel Placed for Continuous Footing.

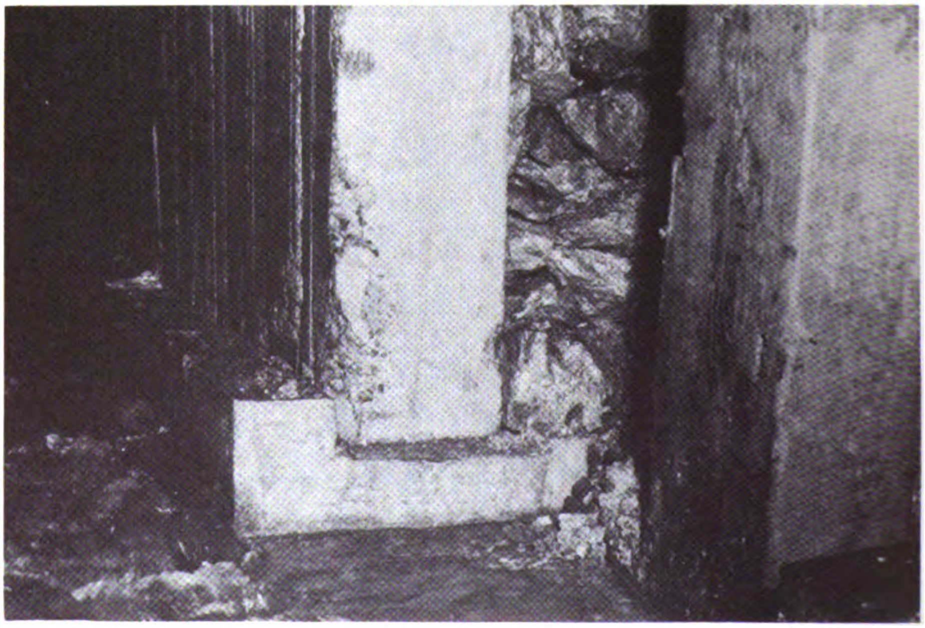

FIGURE 7. - Detail of Footing With Posts.

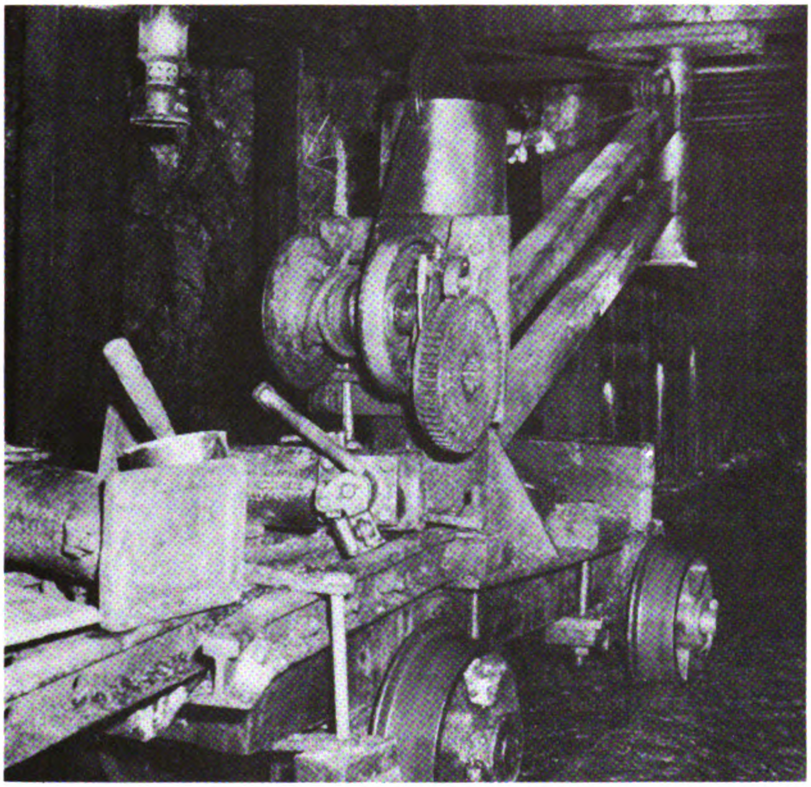

FIGURE 8. - Rear View of Hoist Apparatus or Jumbo.

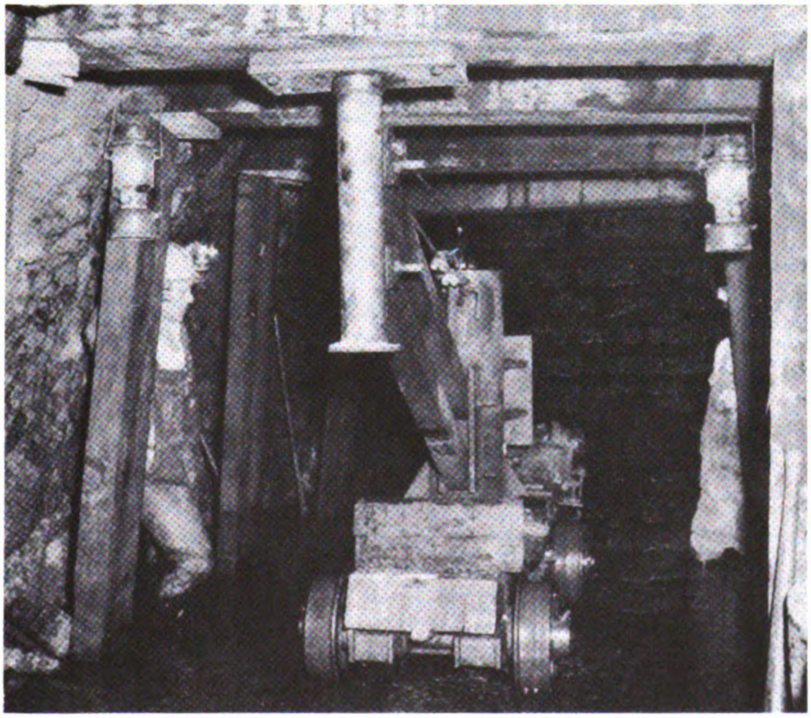

FIGURE 9. - Front View of Hoist Apparatus.

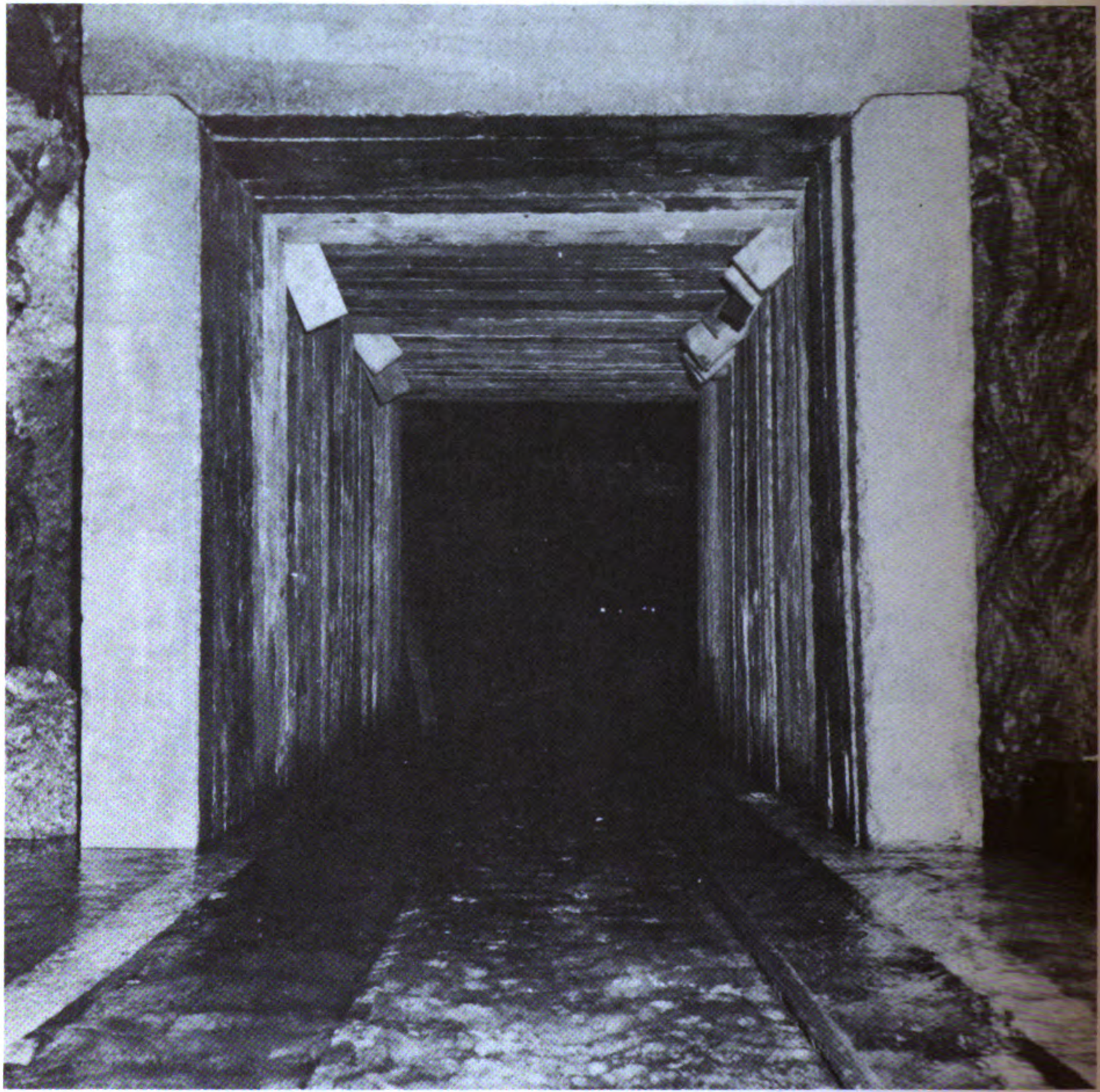

FIGURE 10. - Reinforced-Concrete Sets in Place.

Expensive equipment and highly skilled labor are not needed to place concrete sets, and the work may be started or stopped whenever it is convenient.

The rock penetrated by the tunnel is principally granite and granodiorite, which needs local support where fractured but is otherwise competent. Hydraulic pressure is avoided by the space between sets, through which water and fine clay can escape.

The original costs of installing continuous concrete sets to replace timber is probably 50 percent more than that of replacing timber with creosoted timber; however, with the rapidly rising costs of labor and material, the permanence of concrete sets is a feature that in time will more than offset the original cost.

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